UNIVERSITY ARENA – Journal of Physical Education, Sport and Health, vol. 8, issue 5, 2025, p. 168-177
ISSN 2602-0440, ISSN-L 2602-0440
DOI: https: //doi.org/ 10.62229/UaViii_5_25-24

ONTOGENESIS OF FETAL AND NEWBORN MOVEMENTS: A KINANTHROPOLOGICAL PERSPECTIVE ON OPTIMAL MOTOR DEVELOPMENT

Andreea MANEA MIU[1*], Silvia Violeta TEODORESCU[2]
[1]*National University of Physical Education and Sports, Faculty of Physical Education and Sport, Bucharest, Romania*
[2] *National University of Physical Education and Sports, Faculty of Physical Education and Sport, Bucharest, Romania*
* Corresponding author:andreeamiu80@gmail.com

Abstract. Spontaneous movements represent the first expression of human motor behavior, of the developing central nervous system, reflecting the level of neurological maturation. They have an essential contribution to the organization of neuronal connections and subsequent motor acquisitions.
The first movements appear around the 7th week of gestation and are generated by subcortical neural networks. Professor Christa Einspieler (2004) suggests that the first half of pregnancy is a period of learning and development for most fetal movement patterns, and these continue to develop in the second half of pregnancy and after birth. Motor activity develops as an integrated dynamic system, with fetal movements representing the biological and functional basis of human motor function. They are influenced by genetic, biological and sensory factors, essential for the formation of neural pathways and preparation for extrauterine life. According to current studies and theories, early newborn behaviors follow a continuous adaptive pathway similar to the prenatal motor repertoire of the fetus. Widström and Brimdyr (2011) described nine predictable stages of instinctive behaviors observed during the first hour after birth in undisturbed skin-to-skin contact, enhancing bonding, physiological regulation, and breastfeeding. Bergman (2015) highlights that "the newborn's brain expects to be skin-to-skin after birth," and that postnatal separation acts as a neurodevelopmental stressor.
In preterm infants, this interrupted continuity, abrupt transition to the external environment and an immature nervous system will increase the risk of motor disorders. Dr.Prechtl (2001) stated that "general movements are the most sensitive and specific behavioral markers for predicting later neurological deficits."
From a kinanthropological perspective, these movements are fundamental elements of neuro-motor development, but also early indicators of central nervous system (CNS) maturation. These observations from intrauterine life, but also immediately after birth, may have implications for early assessment and intervention, through the development and application of an integrated model of pediatric kinesiology.

Key words: spontaneous movements, kinanthropology, neuro-motor development, early intervention, motor skills.

Introduction

Movement is the first functional expression of the emerging human being. Previous observations and research have shown that long before birth, as early as intrauterine life in the fluid environment, the fetus initiates its first spontaneous movements. These have been observed sonographically from the

7th week of gestation. Although seemingly purposeless, they show a reflection of the activation and maturation of central neural networks, initially generated by subcortical structures (Prechtl et al., 2001). These movements present a constantly evolving functional repertoire, representing the expression of neuro-motor maturation as well as the biological basis for the newborn's postnatal behaviors.

Over the last decades, numerous studies have demonstrated that these spontaneous fetal movements are not simple reflex reactions, but forms of early motor learning, influenced initially by the intra- and then by the extrauterine environment, essential for the later development of voluntary control (Einspieler et al., 2004). Fetal movement thus becomes an active process, shaped by intrauterine sensory experience, which allows the gradual construction of postnatal regulatory systems - from sucking and breathing to orientation and attachment.

This continuum of motor development, from fetal movements to observable behaviors in the first hours immediately after birth, has been extensively documented by researchers Anne Widström, Kajsa Brimdyr and Katrin Cadwell. The authors have identified a predicted sequence of nine instinctual stages of the healthy newborn infant, carried out exclusively in skin-to-skin contact immediately after birth with the mother's chest (Widström et al., 2011). This staging, which includes: crying at birth, relaxation, awakening, motor activity, crawling, familiarization, sucking, and deep sleep, represents- the faithful reproduction of intrauterine training movements- what the authors call an "imprinted pattern of learned behavior" (Widström et al., 2020).

Dr. Nils Bergman, promoter of the concept of "neurodevelopment centered by direct skin-to-skin contact" (Kangoro Care), emphasizes the idea that "the newborn's brain expects to be on the mother's skin after birth" and that any early separation produces neurobiological stress that affects physiological, motor and emotional regulation. This context of "neurobiological disorganization" disrupts not only autonomic functions, but also the child's ability to display a coherent spontaneous motor repertoire (Bergman, 2015). This perspective is fundamental to understanding how fetal movements prepare the human body for postnatal adaptation, and continuity of contact and movement is key to a healthy transition.

In premature babies, unfortunately this continuity is abruptly interrupted. Preterm birth implies not only an incompletely developed nervous system, but also the absence of the natural context for activating/learning the postnatal motor repertoire. After birth, the preterm infant does not benefit from gentle affective and sensory stimulation, but is often exposed to invasive stimuli, parental separation, and an artificial environment that interferes with spontaneous movements and the development of cortical networks (Cook et al., 2023). These conditions increase the risk of pathological motor patterns and cerebral palsy-like disorders (Ferrari et al., 2002).

Thus, from an integrated perspective, the absence of skin-to-skin contact correlated with reduced quality of spontaneous movements are two important behavioral and physiological indicators of the risks of neuro-motor developmental delay. The application of an assessment model that integrates general movement observation (Einspieler, 2004) and intervention based on sensory contact and affective regulation (Bergman, 2015) may provide an effective direction in early intervention for premature infants.

Early assessment of spontaneous movements, using scientifically validated methods such as General Movements Assessment (GMA), allows early identification of neurological risks. In addition, qualitative scores such as the Motor Optimality Score (MOS) and the AM Adaptation Scale – a proprietary tool developed in-house – provide an integrative picture of the functional and relational adaptation of the newborn. These assessments can guide early physiotherapeutic intervention with a focus on personalization, neuroplasticity and parental involvement in therapy.

Ontogenesis of fetal movements - natural development and neurobiological function

Spontaneous fetal movements occur as an essential manifestation of the activity of the developing central nervous system. The first forms of movement were observed sonographically at around 7 weeks of gestation, in the form of primitive muscle contractions and flexion-extension movements of the trunk (de Vries et al., 1985). These are self-generated and are not the result of external stimulation representing early activation of subcortical neural networks.

According to Dr. Heinz Prechtl, spontaneous fetal movements are classified into several types, the most relevant of which are:

– general movements,
– sucking and swallowing movements,
– rotational movements of the trunk,
– head and limb movements (Prechtl et al., 2001).

Of these, general movements (GMs) have the greatest impact on the later development of motor control, due to their complexity and variability. They are whole-body, slow-paced, fluid, continuous and unpredictable, reflecting the coordinated activity of developing neural systems.

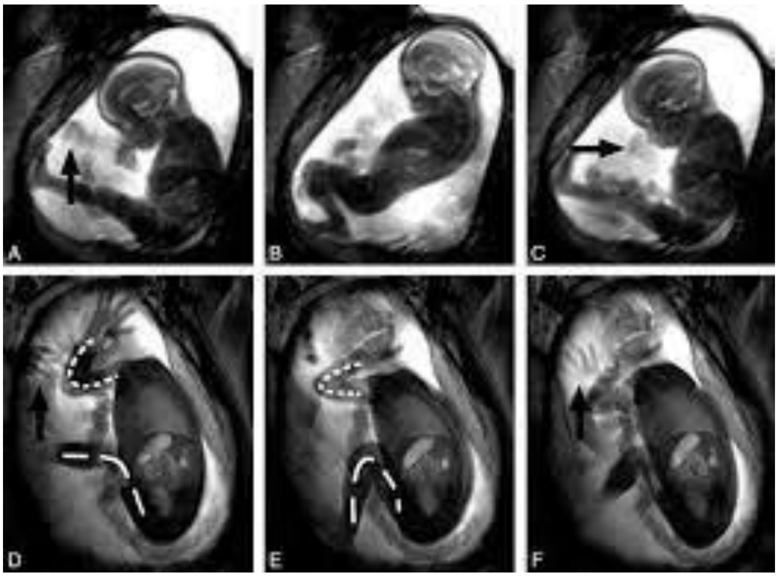

Figure1. Examples from the repertoire of fetal movements at different time intervals (0, 4, 8 seconds), captured by 4D technology - taken from Kurjak et al. (2008).

Following on from these observations, Prof. Christa Einspieler emphasizes that these spontaneous movements not only reflect neurological maturation, but also actively contribute to the development of peripheral and central structures of the nervous system. She emphasizes that in cases of developing brain dysfunction, fetal general movements change their sequence and shape, suggesting a dysfunction of the developing nervous system. Thus, qualitative assessment of these movements may provide early clues about the neurological integrity of the fetus (Einspieler et al., 2021). According to research by Einspieler, Marschik and Prechtl (2004), the ontogenesis of fetal movements can be divided into four broad periods:

– Weeks 7–9: the first trunk contractions and 'startle movements' – short, rapid, involving the limbs and trunk simultaneously – occur. These reflect early activation of primitive motor pathways (de Vries, Visser, & Prechtl, 1985; Einspieler & Prechtl, 2004).
– Weeks 9–12: General movements (GMs) develop, characterized by synchronized involvement of the whole body, with a natural sequence of head, trunk and limb movements. Also at this time, sucking, swallowing, simulations of breathing movements and the first facial movements appear (Einspieler et al., 2004; Kurjak et al., 2010).

- Weeks 13–20: Movements become more varied and rhythmic, including fine flexion-extension of the limbs, isolated movements of the hands and feet, touching the face or uterine wall. The predictable and systematic cranio-caudal order of fetal movement development, essential for the maturation of neuromotor control, is observed (Yigiter & Kavak, 2006).
- Weeks 20–38: Adaptation occurs in the shrinking intrauterine space: motor patterns stabilize, well differentiated sleep-wake periods occur and movements become more efficient. Facial movements – smiling, grimacing, thumb sucking – are a reflection of higher cortical organization (Mirmiran et al., 2003).

Spontaneous movements are not only indicators of neurological integrity, but fulfill fundamental biological and cognitive functions:

- Joint shaping and muscle development – through active movement, the fetus maintains muscle tone and prevents postural malformations.
- Stimulation of the vestibular and somatosensory system – through movements in the amniotic fluid, the fetus develops body awareness (proprioception).
- Creation of synaptic networks – the repetition of movements contributes to the formation of neuronal connections necessary for postnatal motor control (Einspieler & Prechtl, 2005).
- Preparation for the extrauterine transition – sucking, swallowing, rhythmic breathing and cranio-caudal orientation movements are directly correlated with postnatal behavioral milestones.
- According to Widström et al. (2020), these movements constitute a "learned motor script", which will be reactivated in the first hours after birth, under conditions of adequate sensory, skin-to-skin contact with the mother.

From the perspective of neonatal physiotherapy and kinanthropology, understanding these stages is essential. Spontaneous fetal movements provide valuable information about the functioning of the nervous system in the early stages and allow prediction of neurological risks even before overt clinical signs appear. Qualitative assessment of these movements, correlated with the gestational history and birth conditions, is a basic component in the formulation of an individualized therapeutic plan.

Postnatal motor behavior - a reflex of intrauterine training

Birth does not mark the beginning of motor development, but a transition from an intrauterine training space to a new, extrauterine environment, where the acquired motor repertoire is functionally reactivated. In this logic, the motor behaviors observed in the first hours after birth are not completely new, but the result of a precise continuity supported by fetal learning (Einspieler et al., 2004).

Research led by Ann-Marie Widström, together with Kajsa Brimdyr, Karin Cadwell and other collaborators (Widström et al., 2011; 2020) has for the first time systematically described the existence of nine instinctive behavioral stages of the newborn in skin-to-skin contact with the mother in the first hour of life. These include: crying at birth, relaxation, awakening, motor activity, resting, crawling, familiarization, sucking, and deep sleep (Widström et al., 2011; 2020).

Figure 2. Stages of skin-to-skin contact, photo credit, ProMAMA Association.

Each of these behavioral stages reflects movement patterns acquired in intrauterine life and do not occur spontaneously under all conditions. They are activated only in the presence of skin-to-skin contact immediately after birth, which provides the sensory stimuli (warmth, smell, touch, voice) necessary to reactivate learned motor pathways (Widström et al., 2011; Moore et al., 2016).

Tabel 1. Correlations between early postnatal behaviors and spontaneous fetal motor patterns

Postnatal behavioral stage	Correspondence in the repertoire of spontaneous fetal movements	Estimated gestational age	Mecanism neuro-motor	Postnatal activation
The initial cry	Fetal startle reflex	≈ 9 weeks.	Sudden motor activation, respiratory integration	Activate by touch and mom's voice
Waking up and activity	General Movements (GMs)	9-12 weeks	Trunk-head-limb coordination, sensory integration	Activation by touch, mom's voice and eye contact
Crawling to the breast	Alternating lower limb movements	≈ 11 weeks	Primitive locomotor pattern, automatic walking reflex	Ventral activation on the mother
Sucking and swallowing	Fetal sucking and swallowing	12–13 weeks	Suck-breathe-swallow coordination	Stimulated by skin contact and breast odor
Nipple familiarization	Sensory recognition through smell and taste	> 20 weeks	Prenatal sensory imprinting based on the scent of amniotic fluid	Reactivation through the smell and taste of the skin/nipple

According to the model proposed by Bergman (2015), the human brain is programmed to continue development after birth in direct contact with the mother's body. Separation of the mother from the newborn immediately after birth disrupts this process, inducing a stress response that impairs autonomic regulation and adaptive behavioral display. Skin-to-skin contact, in contrast, favors:

– stabilization of vital functions (breathing, heart rate, thermoregulation);
– activation of subcortical networks involved in movement and attachment;
– the synchronization of affective and sensory interaction (Bergman, 2015).

In conclusion, movement is not just a motor act, but becomes a means of integrative communication, a form of self-regulation, exploration, connection and attachment with the parent.

The stages that a newborn baby exhibits immediately after birth follow a logical evolutionary sequence. For example, initial motor activity (stage 4) prepares for crawling (stage 6) and oral familiarization (stage 7) anticipates sucking (stage 8). Through this sequentiality, it has been hypothesized that the newborn is retracing a prenatally learned neurological pathway – what Widström, Brimdyr and Cadwell refer to as the "imprinted behavior pathway" (Widström et al, 2020). The importance of these steps are not just theorized, but have immediate observable physiological consequences: the infant's massaging of the uterus during crawling favors expulsion of the placenta, and sucking triggers oxytocin release, with effects on lactation and attachment (Matthiesen et al., 2001).

Fetal movements and postnatal motor behavior are two factors of the same developmental process, linked through sensory memory, motor learning, and neurophysiological activation. Only in the presence of affective and sensory continuity (skin-to-skin contact) is the newborn able to reactivate the motor repertoire acquired prenatally. This view shifts the paradigm of postnatal motor assessment, providing a scientific basis for early intervention strategies centered on the child and parent.

Prematurity – a discontinuity in motor and emotional development

Preterm birth abruptly disrupts the natural process of motor and affective development by transitioning from the intrauterine environment into a strong, hostile and disorganized sensory environment, such that lack of immediate maternal contact and exposure to neonatal stress can adversely affect movement organization and behavioral regulation (Bergman, 2015).

Figure 3. General cramp-synchronized movements in a premature newborn (34 weeks GA) – clinical observation in dorsal position according to the GMA method.

Atypical spontaneous movements of preterm infants (cramped-synchronized, poor repertoire) are correlated with an increased risk of cerebral palsy, observable early by General Movement Assessment (Einspieler et al., 2004; Ferrari et al., 2002). fragmented and slow expressions of postnatal instinctive stages can also be observed, being dependent on sensory and relational support (Widström et al., 2020).

Care focusing on skin-to-skin contact (Kangoroo care), physiological positioning and gentle intervention tailored to early neuroplasticity may enable behavioral reorganization. An early approach through qualitative assessment and stimulation can facilitate movement recovery and support restoration of developmental continuity (Adde & Einspieler, 2023).

Synchronous tonic contraction of the limbs and trunk is observed, with lack of motor variation, indicating a pathologic pattern of spontaneous movement.

Assessment of fetal movements

Early motor development, rooted in intrauterine life, provides an essential window into the organization and functioning of the central nervous system. In this context, qualitative assessment of the spontaneous movements of the newborn becomes a valuable method to understand the continuity between fetal motor ontogenesis and postnatal behavior. In the first months of life, when neurological plasticity is maximal, observing how the infant moves spontaneously – without external stimulation – reflects the level of integration and maturation of central neural networks (Prechtl et al., 2001).The General Movements Assessment (GMA), a method developed by Heinz Prechtl and consolidated by Einspieler, allows the identification of normal and pathological movement patterns, such as fidgety movements or cramped-synchronized patterns, providing an early prediction of the risk of cerebral palsy or other motor disorders (Einspieler et al., 2004; Ferrari et al., 2002). This qualitative observation is performed between 0–20 corrected weeks and captures the variability, complexity and fluidity of the infant's general movements.

From the GMA is derived the Motor Optimality Score (MOS), a standardized method that more precisely quantifies the quality of spontaneous motor skills in five key domains: presence of fidgety movements, posture, reactivity, transitivity, and variation (Einspieler et al., 2016).

Figure 4. Evaluation position of spontaneous movements in the infant - analysis sequence according to the Prechtl method, in the period of writhing movements.

Spontaneous positioning of the upper and lower limbs is observed, with symmetric postural variation and global spontaneous mobility.

Personalized early intervention

In preterm infants, the natural continuity of motor development is abruptly interrupted by preterm birth, exposing the immature nervous system to an often invasive, stressful and inappropriate extrauterine environment for sensory-motor maturation. For this reason, early intervention is no longer just a therapeutic option, but an essential necessity to support neuromotor development and prevent functional disability (Adde & Einspieler, 2023). Based on the GMA, MOS scores, which allow an integrated assessment of spontaneous movement and behavioral adaptation, a personalized physiotherapeutic model is outlined, in which each intervention is adjusted according to the child's level of neurological maturity and individual response. This model follows the principles formulated by Prechtl, Einspieler and Ferrari: non-invasiveness, gentle stimulation, synchronization with the child's condition and gradual activation of the prenatal motor repertoire (Einspieler et al., 2005). The central element of this model, skin-to-skin contact (KMC), is supported by Bergman's (2015) research that restores the biological and behavioral connection between infant and mother, stimulating spontaneous movements and autonomic regulation.

A fundamental aspect is the active involvement of parents, who are not just bystanders but co-therapists. They are supported to participate in gentle stimulation, positioning, synchronized feeding and interpretation of the baby's nonverbal signals. This approach not only supports motor development, but also strengthens the attachment relationship, reduces stress and increases the effectiveness of the intervention (Brimdyr et al., 2013).

In conclusion, the proposed early intervention supports the continuity of motor development by activating neuro-motor pathways acquired in utero. Spontaneous movement is thus not only an object of assessment, but becomes a fundamental therapeutic tool for neurological reorganization, behavioral adaptation and prevention of developmental disorders.

Figure 5. Skin-to-skin contact (Kangaroo Care) (Source: Penn State Health Children's Hospital, Facebook, May 15, 2025).

Conclusions

Infant motor development begins in the intrauterine period with spontaneous self-generated movements that reflect the progressive activation of the central nervous system. These patterns are not random reactions, but manifestations of an early neuromotor organization that prepares the organism for adaptation to extrauterine life (Prechtl et al., 2001; Einspieler et al., The continuity between fetal movements and spontaneous behaviors of the newborn - especially under skin-to-skin contact – confirms the existence of a prenatally formed sensory and motor memory (Prechtl et al., 2001; Widström et al., 2020).

In premature birth, this continuity is abruptly interrupted, which increases the risk of motor, affective and cognitive impairments. Early exposure to an artificial sensory environment, lacking the physiological regulation provided by the maternal body, can lead to abnormal motor patterns and self-regulatory difficulties (Einspieler & Prechtl, 2005; Bergman, 2015). Qualitative assessment of spontaneous movements and observation of the infant's response to affective stimulation thus become essential for early identification of risks and targeting appropriate interventions.

Furthermore, the prenatal period also plays a very important role in neuromotor development. The healthiest possible maternal lifestyle - including balanced nutrition, stress reduction, moderate physical activity and affective bonding with the fetus, rest – contributes directly to the formation of neural networks, the quality of fetal movements and postnatal adaptive capacity (Kurjak et al., 2010; Lagercrantz, 2016).

In conclusion, spontaneous movement – from intrauterine life and immediately after birth - is a fundamental indicator of neurological maturation and developmental potential. Ensuring continuity between these stages, through early assessment, sensory and relational support, is an essential prerequisite for optimizing child development, especially in preterm infants.

Authors' contributions

All authors listed have made a substantial, direct, and intellectual equal contribution to the work and approved it for publication.

References

Adde, L., & Einspieler, C. (2023). *General movements: A window for early identification of children at risk of developmental disorders*. Early Human Development, 174, 105719. https://doi.org/10.1016/j.earlhumdev.2022.105719

Bergman, N. J. (2015). The neuroscience of birth – and the case for zero separation. *Curationis*, 38(2), a1491. https://doi.org/10.4102/curationis.v38i2.1491

Bergman, N., & Bergman, T. (2013). Whose choice? Advocating birthing practices according to baby's biological needs. *The Journal of Perinatal Education*, 22(1), 8–13. https://doi.org/10.1891/1058-1243.22.1.8

Brimdyr, K., Cadwell, K., Widström, A. M., Svensson, K., Neumann, M., Hart, E. A., & Phillips, R. (2013). The nine stages of skin-to-skin: Practical guidelines and insights from four countries. *Maternal & Child Nutrition*, 9(4), 544–558. https://doi.org/10.1111/mcn.12068

Cook, C., Murphy, C., Sweeney, J., & Holton, T. (2023). Neurodevelopmental care in the NICU: Evidence-based interventions for promoting infant outcomes. *Infant Behavior and Development*, 72, 101817. https://doi.org/10.1016/j.infbeh.2023.101817

Einspieler, C., & Prechtl, H. F. R. (2005). Prechtl's assessment of general movements: A diagnostic tool for the functional assessment of the young nervous system. *Mental Retardation and Developmental Disabilities Research Reviews*, 11(1), 61–67. https://doi.org/10.1002/mrdd.20051

Einspieler, C., Marschik, P. B., Bos, A. F., Ferrari, F., Cioni, G., & Prechtl, H. F. R. (2004). *Prechtl's method on the qualitative assessment of general movements in preterm, term and young infants*. Mac Keith Press.

Einspieler, C., Bos, A. F., Ferrari, F., Cioni, G., & Prechtl, H. F. R. (2016). The Motor Optimality Score–An instrument for early prediction of cerebral palsy. *Clinical Neurophysiology*, 127(2), 197–203. https://doi.org/10.1016/j.clinph.2015.06.003

Ferrari, F., Cioni, G., Einspieler, C., Roversi, M. F., Bos, A. F., & Paolicelli, P. B. (2002). Cramped synchronized general movements in preterm infants as an early marker for cerebral palsy. *Developmental Medicine & Child Neurology*, 44(9), 556–560. https://doi.org/10.1017/S0012162201002597

Kurjak, A., et al. (2010). The neurological evaluation of the fetus and the newborn using 4D ultrasonography. *Journal of Perinatal Medicine*, 38(1), 77–87. https://doi.org/10.1515/JPM.2010.011

Lagercrantz, H. (2016). *The Newborn Brain: Neuroscience and Clinical Applications* (2nd ed.). Cambridge University Press.

Matthiesen, A. S., Ransjö-Arvidson, A. B., Nissen, E., & Uvnäs-Moberg, K. (2001). Postpartum maternal oxytocin release by newborns: Effects of infant hand massage and suckling. *Birth*, 28(1), 13–19. https://doi.org/10.1046/j.1523-536x.2001.00013.x

Moore, E. R., Bergman, N., Anderson, G. C., & Medley, N. (2016). Early skin-to-skin contact for mothers and their healthy newborn infants. *Cochrane Database of Systematic Reviews*, 11, CD003519. https://doi.org/10.1002/14651858.CD003519.pub4

Penn State Health Children's Hospital. (2025, May 15). *Today is National Kangaroo Care Day – a time to celebrate the power of skin-to-skin contact...* [Postare Facebook cu imagine]. https://www.facebook.com/100066362026866/posts/1014450900776968/

Porter, R. H., & Winberg, J. (1999). Unique salience of maternal breast odors for newborn infants. *Neuroscience & Biobehavioral Reviews*, 23(3), 439–449. https://doi.org/10.1016/S0149-7634(98)00043-8

Prechtl, H. F. R., Einspieler, C., Cioni, G., Bos, A. F., Ferrari, F., & Sontheimer, D. (2001). An early marker for neurological deficits after perinatal brain lesions. *The Lancet*, 357(9268), 1377–1381. https://doi.org/10.1016/S0140-6736(00)04582-7

Widström, A. M., Brimdyr, K., Svensson, K., Cadwell, K., Nissen, E., & Ransjö-Arvidson, A. B. (2011). Skin-to-skin contact the first hour after birth: A theoretical model. *Journal of Midwifery & Women's Health*, 56(5), 420–428. https://doi.org/10.1111/j.1542-2011.2011.00040.x

Widström, A. M., Brimdyr, K., Svensson, K., Cadwell, K., & Nissen, E. (2020). The 9 stages of newborn instinctive behavior: A guide for skin-to-skin contact after birth. *Midwifery*, 85, 102657. https://doi.org/10.1016/j.midw.2020.102657

Yigiter, M., & Kavak, Z. N. (2006). Assessment of fetal movements: Clinical significance and future directions. *Perinatal Journal*, 14(2), 65–72.